3D SIMULATION OF SHIFTED LASER PULSE COUPLING TO TIN TARGET

I.P. Tsygvintsev[1,2], A.Yu. Krukovskiy[1,2], V.G. Novikov[1,2]

[1] RnD-ISAN, Troitsk, 142190, Russia
[2] Keldysh Institute of Applied Mathematics RAS, Moscow , 125047, Russia
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Objective

The main goal of the work is to demonstrate the possibilities of self-consistent 3D modeling of EUV source on example of two non-axisymmetric problems:

- Shifted from axis laser beam coupling to droplet
- Oblique laser incidence on planar target

The first type of situation arises from the impossibility of getting the perfect laser targeting in real device: there is always some mismatch, and it's important to find effect of such mismatching on target behavior.

The second type of situation occurs after using of mismatched prepulse, which causes tilted disk-like target.

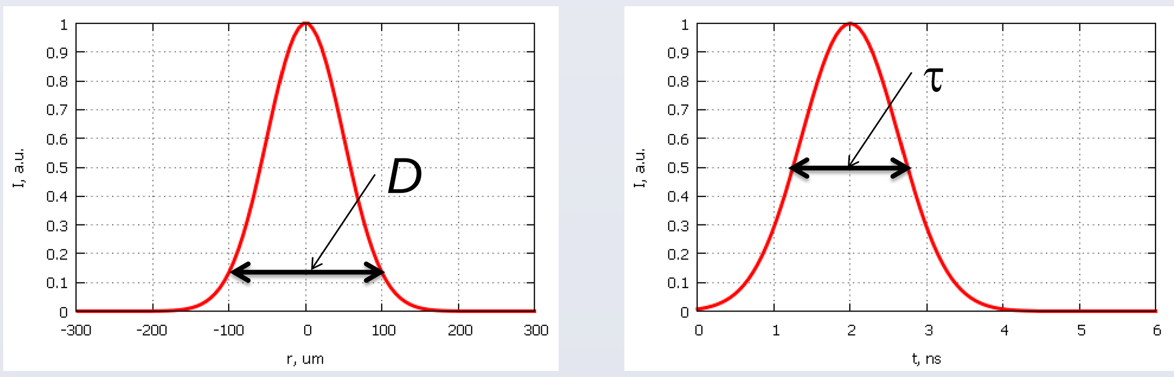
Modeling approach

- Two-temperature one-fluid radiation gas dynamics;
- Non-stationary ionization;
- Diffusion approximation or ray tracing procedure for radiation transport;
- Laser absorption accounting refraction and reflection processes;
- Wide-range tabulated two phase equation of state;
- Opacity and emissivity are calculated by using interpolation between transparent and opaque cases for nonLTE plasma;
- Non-explicit full conservative Euler-Lagrange numerical scheme.

Oblique laser incidence on bulk target

Laser parameters:

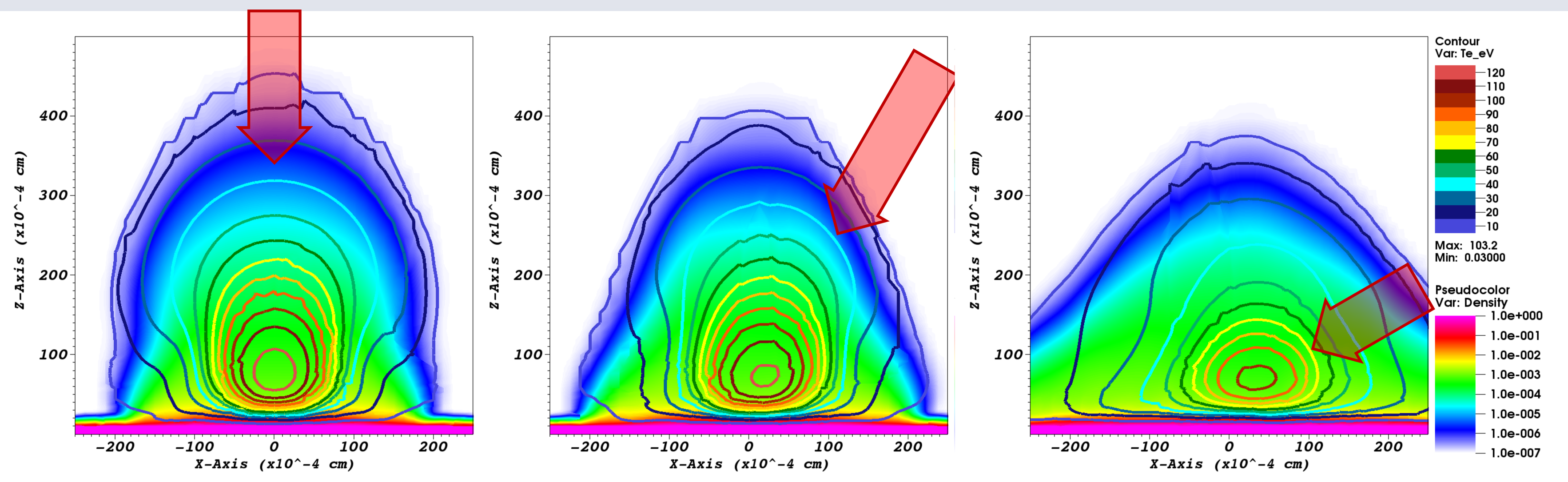
$\lambda = 1.064\,\mu m,$
$D_{e^2} = 200\,\mu m,$
$E = 0.1 J,$
$\tau_{FWHM} = 1.5\,ns,$
$I_{max} = 4\cdot 10^{11}\,W/cm^2$



Density (color) and temperature (lines) distribution on 3 ns

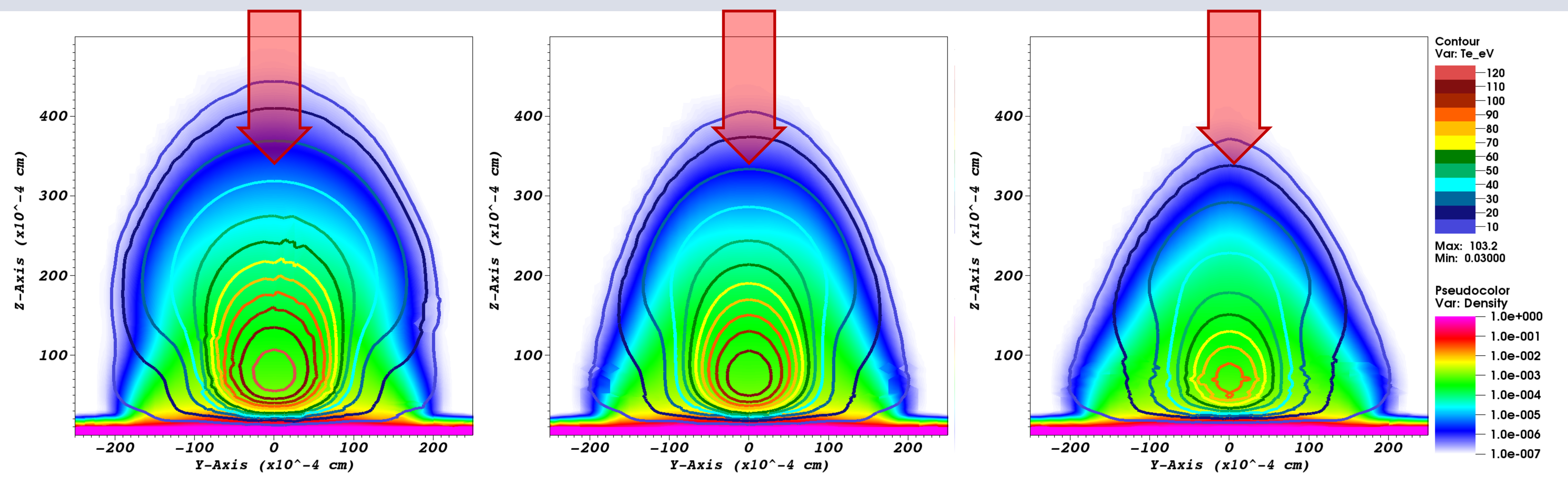
x-z cross-section

Angle 0° | Angle 30° | Angle 60°

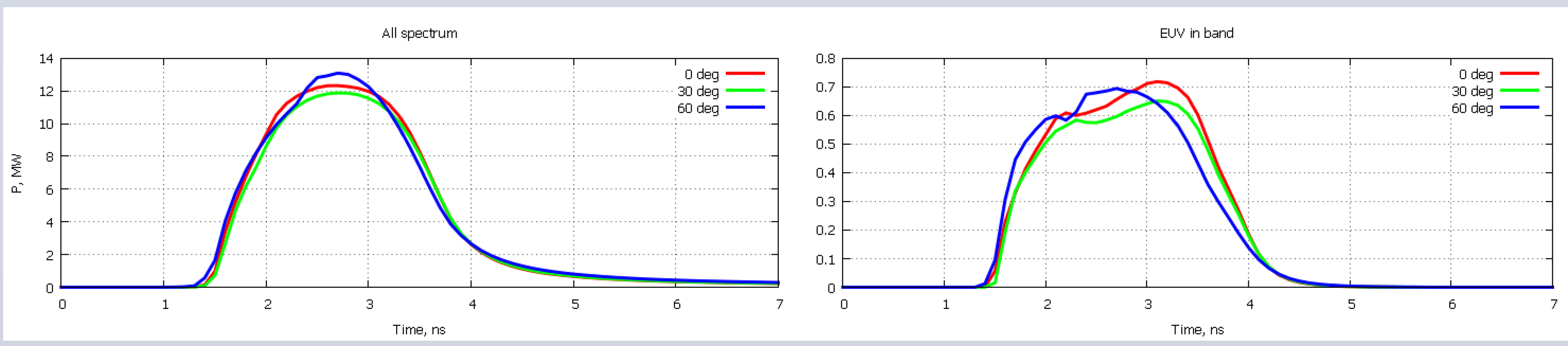


y-z cross-section

Angle 0° | Angle 30° | Angle 60°



Radiation power (from postprocessing ray tracing):



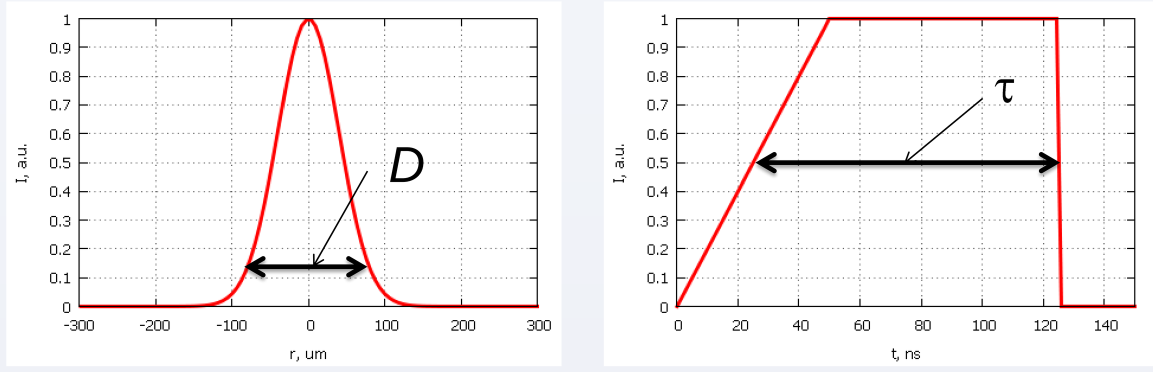
Commentary:

- In investigated cases we did not found significant CE dependency on the angle of laser beam. The main reason for such result is infinite target thickness: laser tilt results only in decrease of effective intensity (cos θ times), and due to the flatness of CE as function of intensity near the optimum, we have practically the same CE in these calculations.
- Calculated CE is 1.8% with in-line short characteristics radiation transport. In-line diffusion method gives ~3.6%, meanwhile postprocessing ray-tracing gives ~1.3 %.

Shifted laser pulse to droplet target

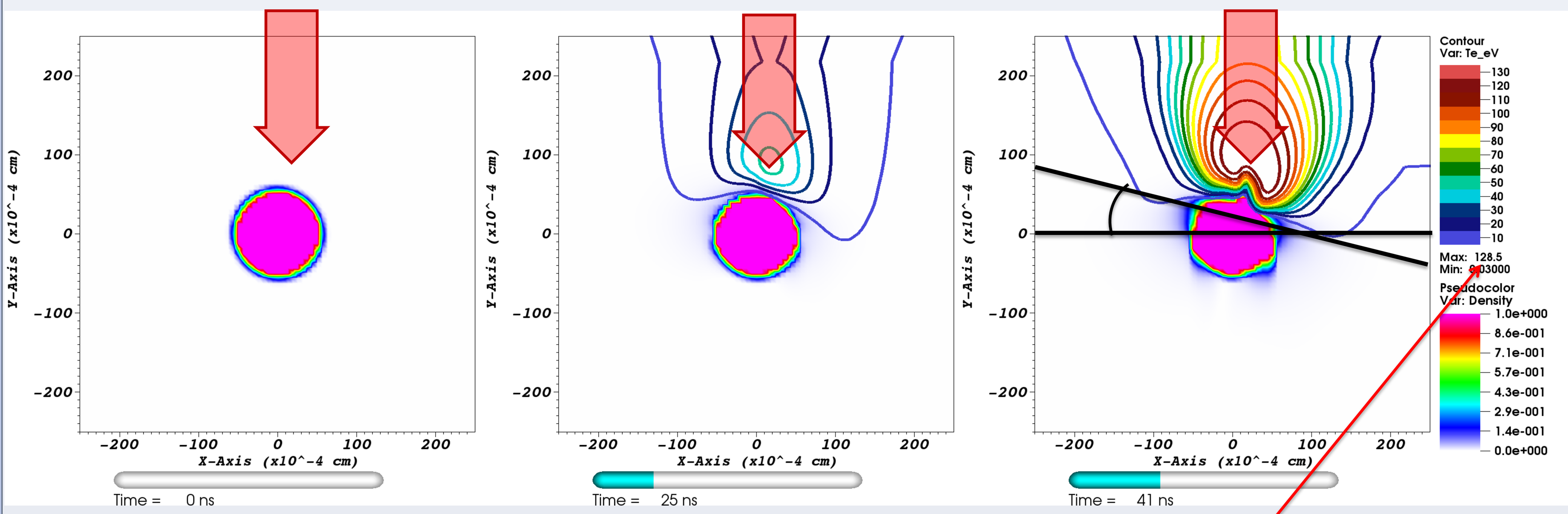
Laser parameters:

$\lambda = 1.064\,\mu m,$
$D_{e^2} = 160\,\mu m,$
$E = 3 J,$
$\tau_{FWHM} = 100\,ns,$
$I_{max} = 3\cdot 10^{11}\,W/cm^2$

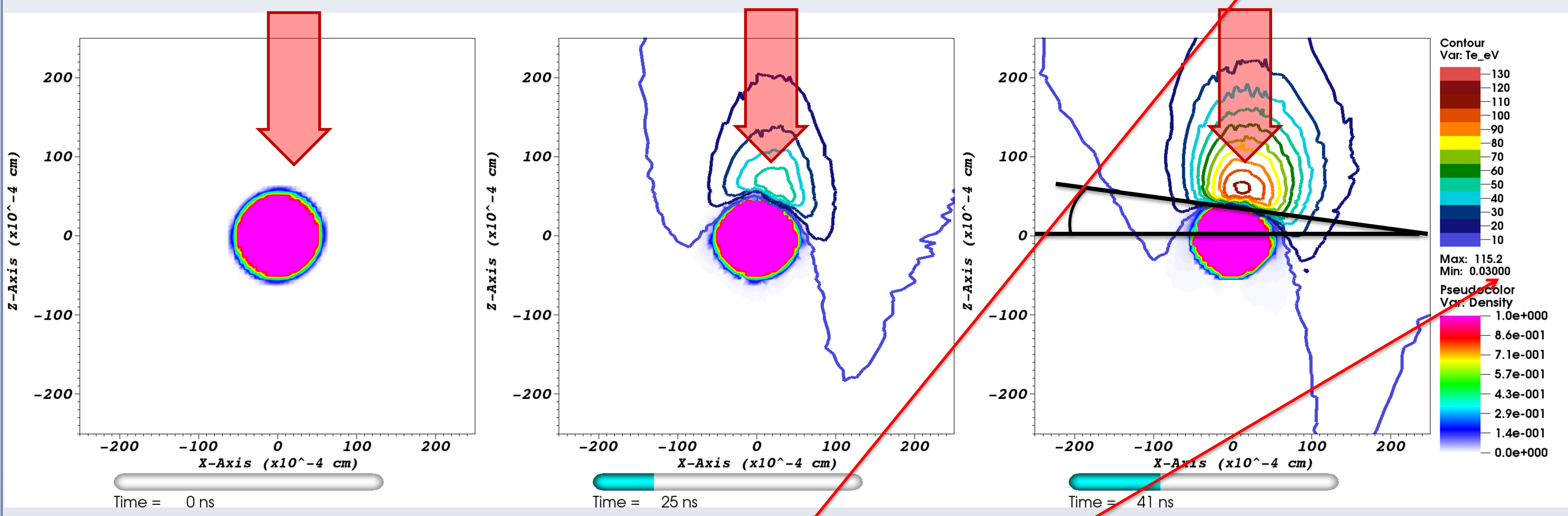


Evolution of target shape with time (16um shift)

2D-simulation (x-y geometry)



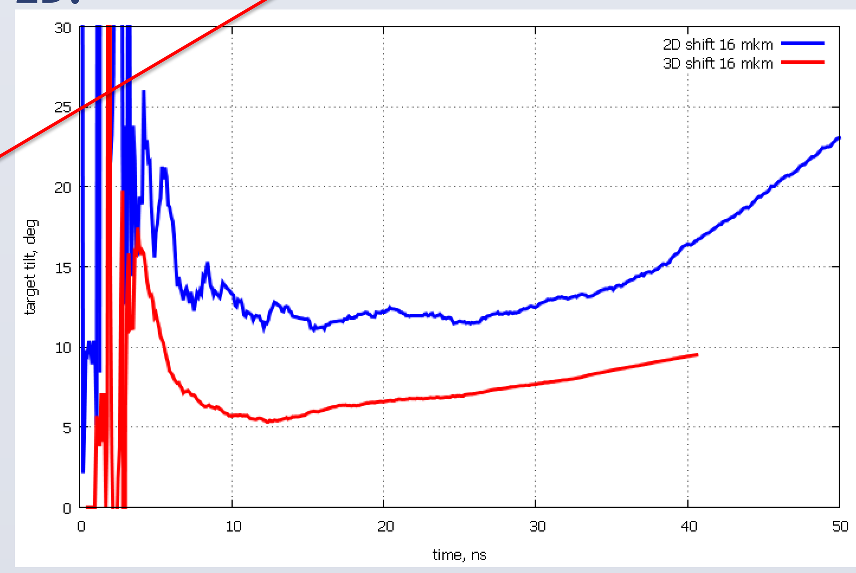
3D-simulation:



3D vs. 2D:

Three-dimensional plasma spreading
→ greater electron density gradient
→ lower laser absorption
→ lower plasma temperature
→ lower pressure on droplet
→ lower tilt angle

(2D , 3D)

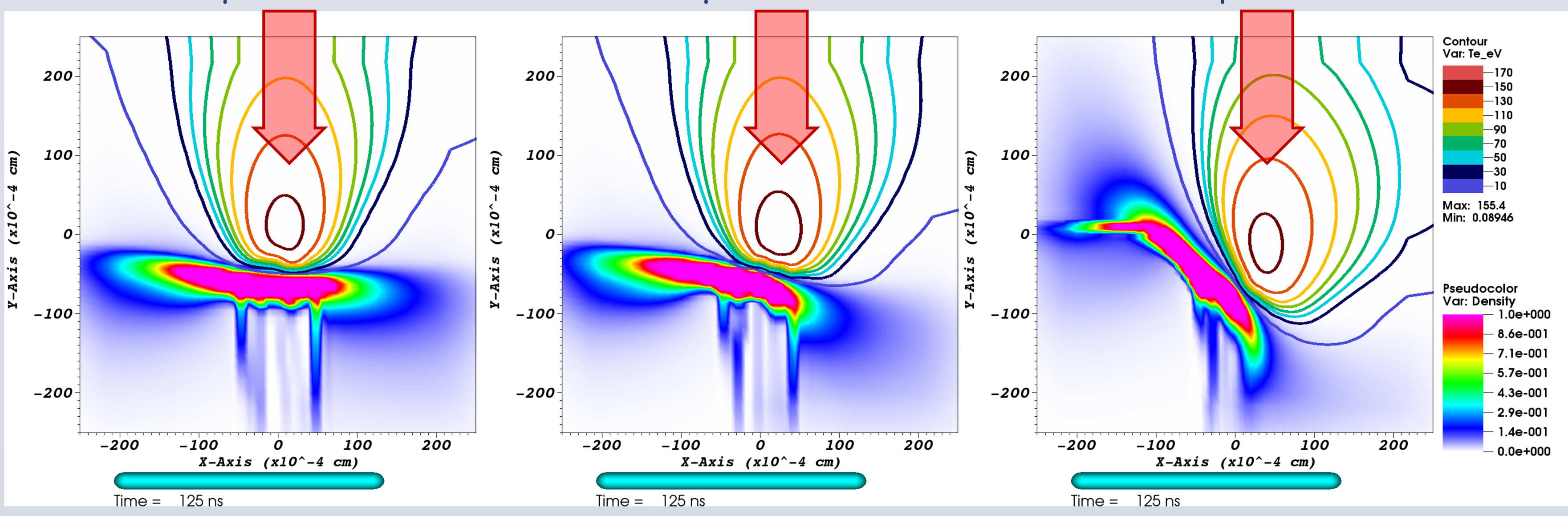


Difference in tilt angle can be as much as 2 times.

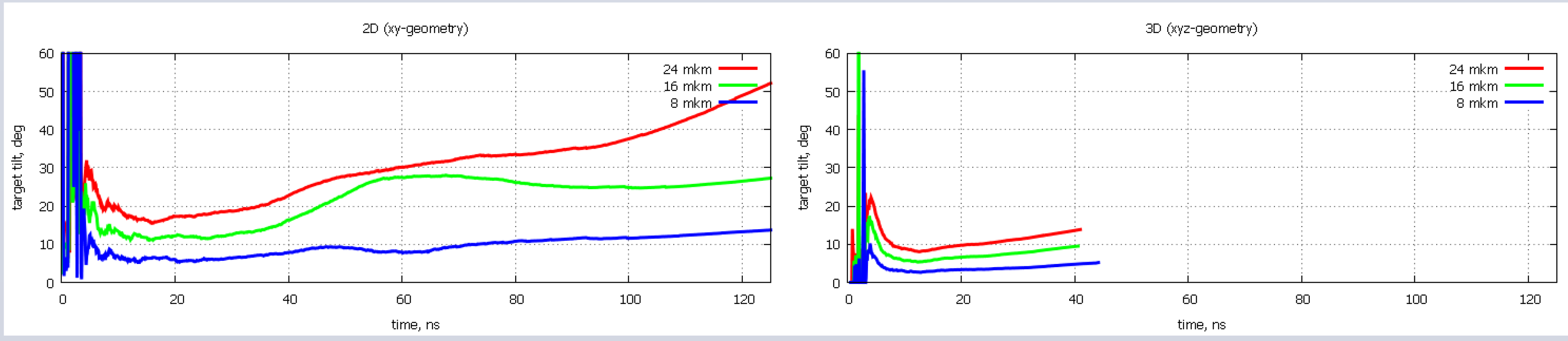
3D calculation has not been finished yet.

Further evolution of target we can see in 2D:

8 μm shift | 16 μm shift | 24 μm shift



Time dependency of target tilt



Conclusion

- 3D-simulation shows lower tilt angle than 2D-simulation. Relative difference can be as great as 2 times. This effect can be caused by lower laser absorption due to larger gradient of electron density.
- Also, it should be noticed, that 2D simulation reveal linear dependency of resulting tilt angle as function of shift. Calculated coefficient ~2° per 1 μm laser shift.
- In 3D simulation we expect coefficient ~1°-1.5° per 1 μm laser shift.